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ABSTRACT

Previous studies indicate increasing, significant univariate and multivariate correlation between reaction time (RT) tasks and intelligence. Using multiple regression analyses, data from an earlier study by Brown and Boretz were reanalyzed to further investigate the relationship between the speed at which an individual is able to process stimuli and that individual's intellectual functioning. With directions to stress speed and accuracy, 40 undergraduates were individually administered three RT tasks of 120 consecutive trials of a set on a NorthStar Horizon microcomputer. The task types were simple reaction time (SRT), discriminative reaction time (DRT), and semantic classification time (SCT). Total Intelligence Quotient (IQ) scores from Cattell's Test of "g" Culture Fair, Scale 3, Form A, were also used in the analyses. Results show statistically significant relationships between intelligence and the rate of acquisition mastery and between the RT tasks and intelligence. Results also support both the speed of processing-ability relationships as hypothesized by Arthur R. Jensen's neural oscillation theory and Hunt's distributed memory model. (BS)

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Reaction Time, Intelligence and Learning
Curve: An Exploratory Investigation

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Abstract

Previous investigations employing three different reaction time (RT) tasks and a measure of intelligence, administered to 40 undergraduates, have indicated increasing, significant, univariate and multivariate correlation between the RT tasks and intelligence. Current, exploratory analyses have further shown statistically significant relationships between intelligence and the rate of acquisition mastery, as well as the mean RT at acquisition of those RT tasks involving more complex cognitive processing. Results are discussed in terms of Jensen's neural model and Hunt's distributed model.

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Introduction

The investigation of the relationship between reaction time (RT) and intelligence and/or verbal ability has both a long and often times inglorious past, dating back to the works of Donders, Galton and Cattell, and temporarily curtailing with the work of Wissler and the introduction of Binet's scale of intelligence (see Jensen, 1980 for a complete review). In recent years, however, renewed interest in the relationship has grown with the development of more sophisticated techniques of measurement and the prominence of information processing theories.

The work of Jensen and his associates (Jensen, 1978; Jensen & Muro, 1979) has especially sparked renewed interest in the field of intelligence and RT. Jensen (1978) hypothesized that RT, defined as the time from the onset of a stimulus to the detection of said stimulus by a subject, would be related to intelligence as measured by the Raven's Standard Progressive Matrices (Raven, 1947). The results of these studies have indicated that both RT and the speed of motor movement of a subject, movement time (MT), are negatively correlated with the intelligence measures. Consequently, Jensen has

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concluded that RT and MT are indicative of different components of fluid or information processing capacities. Jensen has further interpreted these findings in terms of a neural oscillation model (see Jensen, 1978 for further details).

Investigations of RT and intellectual measures are not unique to Jensen's work, and has been the specific focus of investigations regarding such factors as verbal ability and memory in reference to a number of information processing models (Boretz & Borwn, 1984; Brown & Boretz, 1983; 1984; Brown, Kaye, Hall & Post, 1981; Cohen, 1977; Goldberg, Schwartz & Stewart, 1972; Hunt, 1978; Hunt, Frost & Lunneborg, 1973; Hunt, Lunneborg & Lewis, 1975). In general, this research utilizing a number of different RT paradigms has demonstrated the existence of relationships between certain measures of memory and RT, as well as some relationships between verbal ability and RT. However, the findings regarding intelligence and RT are less than clear. Lunneborg (1977), obtaining mixed results, has hypothesized that the inconsistent findings may be due to sample selection, choice of psychometric instrument, measurement apparatus employed, RT paradigm utilized

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and level of cognitive processing accessed.

In several attempts to address a number of these issues, and in particular the RT paradigms utilized in relation to the level of cognitive processing, Brown and Boretz (1983); Brown et al. (1981) and Brown, Kaye, Post and Hall (1979) failed to replicate Jensen's findings utilizing different RT paradigms. In particular, our earlier work (Brown & Boretz, 1983) investigating the relationship between RT and verbal ability (as measured by several subtests on the WAIS-R) developed two RT tasks designed to measure different amounts of cognitive processing. Their hypothesis, that as the complexity of the task increased, the increasing cognitive processing would negate any purely neural oscillation effect, and thereby result in a decreased relationship between RT and measures of verbal ability, was not confirmed. Furthermore, no pattern of significant correlations between RTs and selected WAIS-R subtest scores were discovered.

A subsequent investigation (Boretz & Borwn, 1984), employing three RT tasks, has indicated an increasing, significant, univariate and multivariate correlation, between the RT tasks and intelligence, supporting the

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Jensen model. With the previously stated research as a foundation, the current exploratory investigation was undertaken in an attempt to develop a combination of RT parameters able to predict cognitive ability. Based on our earlier findings (Boretz & Brown, 1984), we hypothesized that as the complexity of the task increased, the relationship between RTs and intelligence would also increase due to the additive effects of intellectual factors such as memory, cognitive strategy and experience would increase. Further, it was hypothesized that as the complexity of the RT task once again increased, the relationship between acquisition rate (AR), the rate at which maximum speed of response was reached and maintained, and the measure of intelligence would also increase. Finally, it was hypothesized that by subtracting simple reaction time from the two more complex tasks, RT measures less contaminated by motor activity could be obtained; the resulting variables providing additional parameters of RT able to account for a significant amount of the variance within the intelligence measure.

The present study is therefore a further investigation of the RT-intelligence relationship.

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Utilizing the data generated by Boretz and Brown (1984), further analyses have been conducted in reference to the relationship between intelligence and the rate of acquisition or mastery of those reaction time tasks employed.

Methods

Subjects The subjects were 40 undergraduate students at the University of Connecticut (9 males and 31 females), who were haphazardly selected from an existing educational psychology subject pool.

Apparatus A NorthStar Horizon microcomputer equipped with a Televideo 950 black and white monitor and a Mountain Hardware 100,000 day clock was utilized for all aspects of stimulus presentation as well as measurement and recording of RT data.

Procedures All subjects were individually administered three RT tasks of 120 consecutive trials of a set. Standardized directions were individually read to each subject prior to each RT task stressing both speed and accuracy. All subjects received the tasks in the following order: Simple reaction time (SRT), Discriminative reaction time (DRT) and Semantic classification time (SCT).

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SRT task. A 77mm X 57mm box was presented in the center of the computer screen in which the target, an ampersand (&), would appear at random locations and at random time intervals from the onset of the box to decrease the probability of guessing when the target would appear. The box was utilized to restrict the subject's field of visual search for the target. Subjects were instructed to press either of two predesignated keys as quickly as possible to indicate the presence of the target within the box. Subjects were instructed to rest their fingers upon one of the response keys to minimize the effect of movement time in the task. Figure 1 presents an illustration of a sample screen presentation of the SRT task.

Insert Figure 1 About Here

DRT task. Subjects were required to detect the presence of either an "X" or an "O" within a box identical to that used in the SRT task. Once again, the targets were presented at random locations within the box and at random time intervals following the presentation of the box to decrease the probability of guessing when the target would appear. Subjects

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were instructed to respond differently to each of the two targets, pressing one key for the "X" and the other for the "O". Both targets were programmed to appear in a pseudo-random order an equal number of times across the 120 trials. Figure 2 presents a sample illustration of the screen presentation for the DRT task.

Insert Figure 2 About Here

SCT task. Subjects were informed that the third task was quite different from the first two and instructed that they would be required to make a semantic judgement regarding two words. In this task a categorical noun (i.e., FRUIT) would be presented slightly above the center of the screen preceeded by the word "CATEGORY:". At the subject's discretion, he/she was to press one key to cause the categorical noun to be cleared from the screen and have a second noun appear in capital letters slightly below center of the screen (i.e., APPLE). All stimuli for the third task were high frequency nouns selected from either the Battig and Montague (1969) or Thorndike and Lorge (1968) word norms. Subjects were

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requested to respond "same" or "different" regarding the relationship between the category noun presented and the subordinate noun presented second. Two keys were predesignated, one for each response. Subjects controlled the duration of presentation for the category noun but, were encouraged to respond as quickly and as accurately as possible for the subordinate noun. Figure 3 presents an illustration of the series of the SCT task procedures.

Insert Figure 3 About Here

Psychometric measures. Prior to the administration of the RT tasks, all subjects were administered the Test of "q" Culture Fair, Scale 3, Form A (Cattell & Cattell, 1963), a standardized group intelligence test. This instrument is reported to be very reliable with Split-half and Test-Retest reliability coefficients ranging from .82 to .85 and a concurrent validity coefficient of .69 with other standard measures of intelligence (Cattell & Cattell, 1963). Total IQ scores were used for the purposes of statistical analysis.

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Results

The previous investigation employing the 3 above mentioned RT tasks in conjunction with the Test of "g" Culture Fair (Cattell & Cattell, 1963) yielded increasing, significant, univariate and multivariate correlations between the RT tasks and intelligence. Thus, Jensen's original hypothesis that as task complexity increases, the correlations between RT and intelligence increases was supported. Simply stated, those subjects who were able to process information faster (shorter RTs) were also the subjects that achieved higher scores on the intelligence test. In employing the RT variables to predict intelligence scores a significant, multiple correlation was computed producing an R^2 of .228, indicating that approximately 23 percent of variance associated with the intelligence scores could be explained by the RT paradigms employed. A detailed discussion of the methodologies and statistical analyses used is presented in Boretz and Brown (1984).

In attempting to improve the ability to predict intelligence by means of a combination of RT paradigms, arcsine transformations of the three original RT tasks were performed in order to establish

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homoscedasticity prior to calculating acquisition rates (AR)² and acquisition reaction times (ART). The transformed RTs of each task were then divided into 12 groups of 10 consecutive RTs for each subject. AR was determined for each task by locating the first block of ten responses in which no significant change in mean response rate was noted in reference to the block directly following it ($p < .05$). In this manner ART, the mean RT for the block of ten responses in which AR was reached, was also computed for the SRT, DRT-SRT and SC-SRT were calculated in an attempt to obtain RT measures less contaminated by movement time, and thereby providing additional parameters of RT able to account for the variance within the intelligence measure.

It should be further noted that the above calculations and consequent transformations were performed after verifying that the percentage of error across tasks ranged between 1.3% to 7.2% (with a mean of 3.6), establishing that the correlation between the "X" choice and the "O" choice of the DRT task was equal to .9238 ($p < .01$), and that the correlation between matched and nonmatched category sets of the SCT task was equal to .911 ($p < .01$). Only

correct responses were used in the statistical analyses.

Subsequent to the above computations, individual and group means and standard deviations were calculated for the reaction time variables, the acquisition variables and the intellectual measure. Group means and standard deviations are presented in Table 1.

Insert Table 1 About Here

The analysis of the data was conducted in two separate phases. The first phase consisted of conducting univariate correlations between the intelligence and the RT data. The second phase employed the use of multiple regression techniques to predict intelligence based on RT performance. The univariate correlations are presented in Table 2.

Insert Table 2 About Here

As can be seen from table 2, there was no significant relationship identified between SRT and intelligence as measured by the Culture Fair test. However, both DRT and SC were significantly correlated with intelligence, as were DRT-SRT and SC-SRT. Jensen's original hypothesis and the

hypothesis of those previously cited, that there is no relationship between SRT and intelligence increase, have been supported by the present study. Of further interest is the finding DRT-SPT and SC-SRT produce correlations of a higher magnitude in reference to intelligence than do DRT or SC respectively. This once again supports the hypotheses of a number of the previously cited authors, that by subtracting SRT, a possible movement time contaminant, from DRT and SC, increase correlations between RT and various measures of cognitive ability will be produced. Finally, as hypothesized, as the complexity of the RT task increased, the relationship between AR and ART to intelligence also increased. Although correlated to intelligence in a non-significant manner, an increase in the size of the correlations was obtained between acquisition rate for simple reaction time (AR for SRT) and acquisition rate for discriminative reaction time (AR for DRT). Further, the correlation between acquisition rate for semantic classification (AR for SC) and intelligence is not only larger than the correlation between AR for DRT and intelligence, but also reaches significance. Finally, similar increases and levels

of significance are obtained for the correlations of intelligence to acquisition reaction time for the SRT, DRT and SC tasks (ART for SRT, ART for DRT, ART for SC).

As has been stated, the hypotheses relating SRT, DRT, SC, DRT-SC and SC-SRT to intelligence in both a univariate and multivariate fashion has been demonstrated by a number of researchers, including the current authors. Therefore, stepwise multiple regression analyses were conducted in an attempt to determine the amount of variance within the intelligence measure which could be alone explained by the RT learning curve variables.

Insert Table 3 About Here

In the first analysis in which the three AR variables were used to predict IQ, AR for SC significantly accounted for 13 percent of the variance. In the second analysis using the three ART variables, ART for SC significantly predicted 17 percent of the variance associated with the intelligence measure. Finally, a multiple regression analysis combining the six RT learning curve variables in an

attempt to predict intelligence resulted in an identical model to that of the second analysis.

Discussion

The overall purpose of this study was to investigate the relationship between the speed at which an individual is able to process stimuli and the intellectual functioning of that individual. Jensen (1978), Jensen and Murro (1979), Sen and Jensen (1983), and Vernon (1981) have proposed that various measures of RT are inversely correlated with intelligence, and that as the task complexity increases, so does the relationship with intelligence. Others, such as Lunneborg (1977) have found mixed results, concluding that relationships between RT and ability vary according to the specific variables and paradigms employed.

Whether interpreted in reference to Jensen's neural oscillation theory or in reference to Hunt's Distributed Memory Model, the above researchers have generally concluded that those subjects having high intellectual abilities are able to encode, manipulate and analyze incoming stimuli more efficiently. Part of this efficiency has been seen as speed of processing ability by those advocates of RT research.

The results of the present study are supportive of the speed of processing-ability relationship as hypothesized by Jensen and his colleagues, and also add support to the Hunt model regarding the relationship between RT and verbal ability. However, as has been pointed out by the above authors, no RT paradigm or combination of paradigms has been as successful in predicting cognitive ability as a number of currently available standardized psychometric instruments presently used for intellectual assessment. For example, Boretz and Brown (1984) were able to predict only 23% of the total variance of the Test of "g": Culture Fair.

The current study was conducted in an attempt to develop specific RT paradigms that would be able to predict intelligence as measured by a standardized intelligence test. Two such paradigms AR for SC and ART for SC have been tentatively identified as being able to independently predict approximately 13 and 17 percent respectively of the variance explained by the Cattell test. Yet, in attempting to combine these two variables within a stepwise multiple regression to improve predictability, problems relating to the entry of the second predictor variable are

encountered, suggesting that both AR for SC and ART for SC share the same variance with respect to intelligence.

These findings appear to support Lunneborg's contention that relationships between RT and ability vary according to the specific variables and paradigms employed. Further, it may be hypothesized that a number of RT paradigms being currently used as predictors of ability are for the most part predicting the same or a similar variance with reference to the criterion variable. This would be in agreement with Jensen's suggestion that RT has only been able to predict a limited amount of intelligence because of the nature of the IQ tests used within RT research. Jensen, claiming that most psychometric ability instruments measure "g" inadequately and that RT is primarily a measure of "g", has concluded that small correlations are inevitable.

Future RT-ability research must therefore concern itself not only with the choice of RT paradigms used, but also with the choice of ability measures employed. Rather than merely haphazardly gathering together a number of RT paradigms in conjunction with a psychometric instrument which happens to be available,

RT researchers must consider the inter-relatedness of their variable choices and the affects this may have upon results. AR for SC and ART for SC, representing measures of higher level cognitive functioning as measured by an RT task that has been corrected for homoscedasticity, may provide researchers with not only a greater choice of RT paradigms, but also with variables that when incorporated properly with a combination of RT paradigms will be better able to predict cognitive ability.

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Footnotes

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²Acquisition Rate (AR) ranged between 1 and 11, indicating the block of 10 trials in which there was no significant decrease in RT in the following block of trials.

TABLE 1

Group Means And Standard Deviations
For Reaction Times and IQ

Task	Mean	Standard Deviation
SRT	313.04	41.64
DRT	459.54	55.83
SC	768.92	159.22
DRT-SRT	146.51	51.40
SC-SRT	455.88	147.26
AR for SRT	2.77	1.37
AP for DRT	2.65	1.82
AR for SC	3.60	2.06
ART for SRT	0.0003	0.0000
ART for DRT	0.0002	0.0000
ART for SC	0.0001	0.0000
IQ	115.82	13.63

TABLE 2

Correlations Between Mean RT And Intelligence

	SRT	DRT	SC	DRT-SRT	SC-SRT	AR for SRT	AR for DRT	AR for SC	ART for SRT	ART for DRT	ART for SC	IQ
SRT		0.475**	.407**	-0.294*	0.158	0.263	-0.081	-0.113	-0.788**	-0.484**	-0.470**	0.012
DRT			.595**	0.701**	0.0509**	0.192	0.255	-0.200	-0.279*	-0.831**	-0.634**	-0.328*
SC				0.317*	0.966**	-0.102	0.193	-0.171	-0.336*	-0.563**	-0.859**	-0.398**
DRT-SRT					0.425**	0.003	0.343*	-0.126	0.335*	-0.510**	-0.308*	-0.366**
SC-SRT						-0.184	0.232	-0.153	-0.141	-0.472**	-0.796**	-0.433**
AR for SRT							0.143	-0.123	-0.187	-0.155	-0.015	-0.028
AR for DRT								-0.223	0.088	-0.299*	-0.197	-0.246
AR for SC									0.158	0.028	0.328*	0.366**
ART for SRT										0.314*	0.397**	-0.045
ART for DRT											0.505**	0.132
ART for SC												0.410**

Note: * $p < .05$
 ** $p < .01$

Reaction Time
24

TABLE 3

Stepwise Multiple Regression Using
AR For SRT, AR For DRT And AR For SC
To Predict I.Q.

Step	Variable Entered	R	R ²	Beta	F	Prob.
1	AR for SC	.364	.133	.364	5.664	.023
2	Probability of F-to-enter = 0.050. Limits reached					

Stepwise Multiple Regression Using
ART For SRT, ART For DRT And ART For
SC To Predict I.Q.

Step	Variable Entered	R	R ²	Beta	F	Prob.
1	ART for SC	.412	.170	.412	7.559	.009
2	Probability of F-to-enter = 0.050. Limits reached					

Stepwise Multiple Regression Using AR
For SRT, AR For DRT, AR For SC, ART For SRT,
ART For DRT And ART For SC To Predict I.Q.

Step	Variable Entered	R	R ²	Beta	F	Prob.
1	ART for SC	.412	.170	.412	7.559	.009
2	Probability of F-to-enter = 0.050. Limits reached					

FIGURE 1

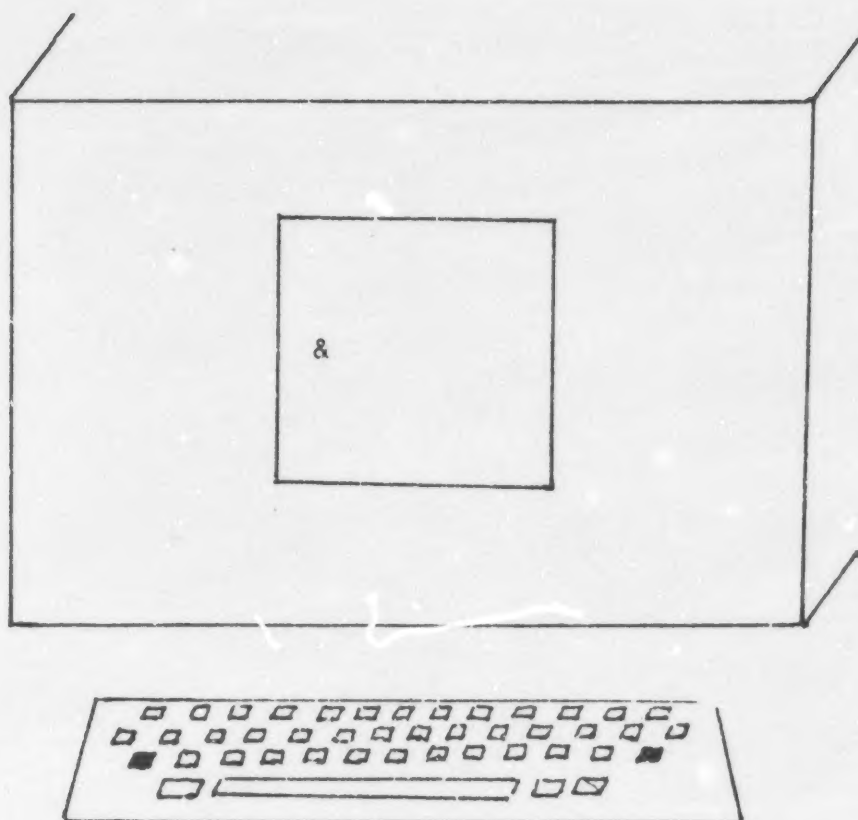


FIGURE 2

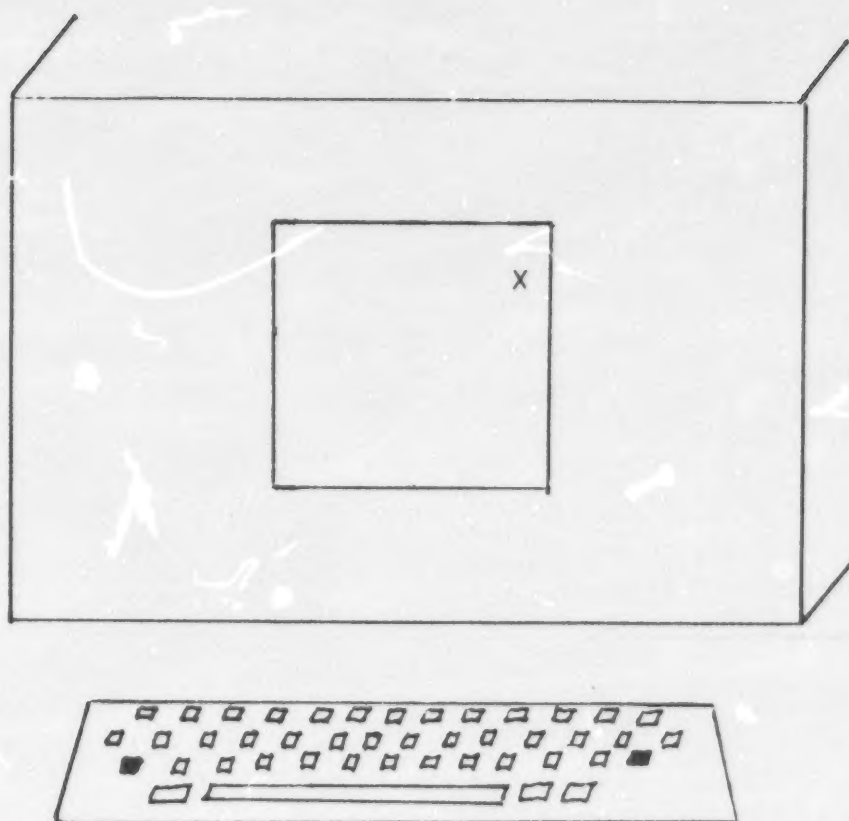


FIGURE 3

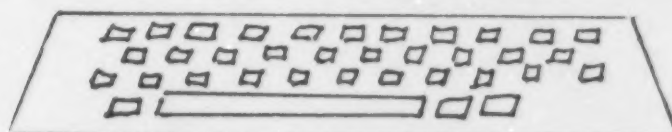
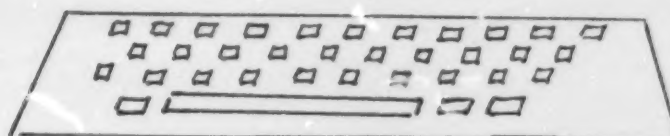
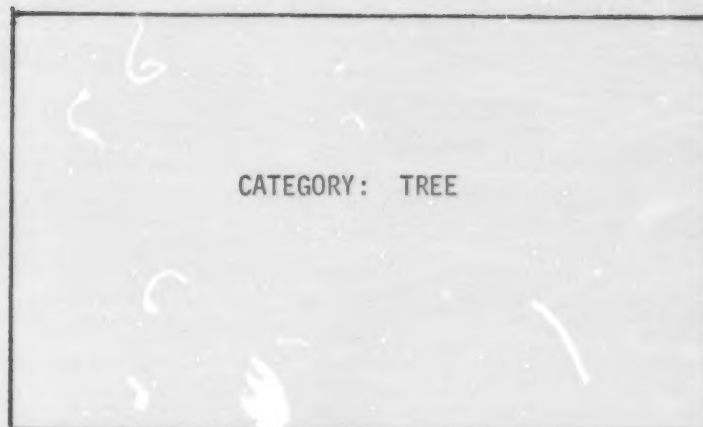


Figure Captions

Figure 1. Sample presentation of computer display for Simple Reaction Time task (SRT).

Figure 2. Sample presentation of computer display for Discrimination Reaction Time task (DRT).

Figure 3. Sample presentation of the series of presentations for the Semantic Classification task (SC).